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## VLA Observations of H I in the Circumstellar Envelopes of AGB Stars

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**Abstract.** We present the results of a VLA search for H I emission in the circumstellar envelopes of five nearby AGB stars: RS Cnc, IRC+10216, EP Aqr, R Cas, and R Aqr. We have detected emission coincident in both position and velocity with RS Cnc, implying that the emission arises from its extended envelope. For R Cas, we detected weak ( $5\sigma$ ) emission that peaks at the stellar systemic velocity and overlaps with the location of its circumstellar dust shell and thus is probably related to the star. Toward IRC+10216 and EP Aqr, we detected multiple, arcminute-scale H I emission features at velocities consistent with the circumstellar envelopes, but spatially offset from the stellar positions; in these cases we cannot determine unambiguously if the emission is associated with the stars. In the case of IRC+10216, we were unable to confirm the detection of H I in absorption against the cosmic background previously reported by Le Bertre & Gérard. We detected our fifth target, R Aqr (a symbiotic binary), in the 1.4 GHz continuum.

### 1. Summary

Recent single-dish surveys have established that neutral atomic hydrogen (H I) is common in the circumstellar envelopes of evolved, low-to-intermediate mass stars undergoing mass-loss (Gérard & Le Bertre 2006 and references therein). The large extents of the envelopes detected in H I (up to  $\sim 2$  pc) imply that H I probes different regions of the envelope than CO or other molecular tracers and thus can trace mass-loss over very large time-scales — up to  $\sim 10^5$  yr. Studies of the 21-cm emission from circumstellar envelopes can therefore provide important new constraints on atmospheric models of AGB stars, the physical conditions in their extended envelopes, and on the rates, timescales, and geometries of their mass-loss.

We have recently undertaken a VLA H I imaging survey of five nearby AGB stars: RS Cnc, IRC+10216, EP Aqr, R Cas, and R Aqr. H I detections of four of these targets (RS Cnc, EP Aqr, and R Cas in emission and IRC+10216 in absorption) have been published previously based on single-dish observations (Le Bertre & Gérard 2001, 2004; Gérard & Le Bertre 2003, 2006).

We have confirmed the presence of H I emission coincident in position and velocity with the semi-regular variable RS Cnc, implying that the emission is indeed associated with its circumstellar envelope (Figure 1). We estimate a total H I mass for this material of  $M_{\text{HI}} \approx 1.5 \times 10^{-3} M_{\odot}$  (for  $d = 122$  pc). The morphology of the emission suggests that a component of the mass-loss is highly asymmetric. From the H I data we derive a recent mass-loss rate of  $\dot{M} = 1.7 \times 10^{-7} M_{\odot} \text{ yr}^{-1}$ , comparable to previous estimates based on CO observations.

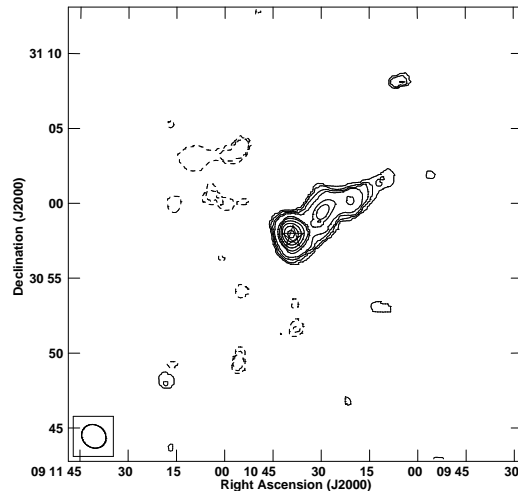


Figure 1. VLA H I total intensity map of a 30' region around RS Cnc. The contour levels are  $(-16, -8, 8, 16, 24 \dots 86) \times 1.25 \text{ Jy beam}^{-1} \text{ m s}^{-1}$ . A star symbol marks the optical position of the star.

For the Mira variable R Cas we have detected weak ( $5\sigma$ ) emission centered at the systemic velocity of the star. The morphology of the emission is consistent with a partial shell-like structure with a radius  $r \sim 100''$ . This structure overlaps with the dust shell previously detected by Young et al. (1993a,b), and we estimate for it an H I mass of  $M_{\text{HI}} \approx 5.3 \times 10^{-4} M_{\odot}$ , assuming  $d = 160 \text{ pc}$ .

Toward two other targets (the carbon star IRC+10216 and the semi-regular variable EP Aqr) we have detected multiple arcminute-scale H I emission features at velocities consistent with the circumstellar envelope, but spatially offset from the position of the stars. In these cases we cannot determine unambiguously whether the emission arises from material within the circumstellar envelope or, instead, from the chance superposition of Galactic H I clouds along the line of sight.

We detected our fifth target, R Aqr (a symbiotic star with a hot companion), in the 1.4 GHz continuum with a flux density  $F_{1.4\text{GHz}} = 18.8 \pm 0.7 \text{ mJy}$ . R Aqr is a well-known radio source, and the continuum emission likely arises primarily from free-free emission from an ionized circumbinary envelope. However, we did not detect any neutral hydrogen associated with this system.

A more extensive discussion of these results can be found in Matthews & Reid (2007).

## References

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